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EFFECT OF AGE, OCCUPATION, AND PHYSICAL TRAINING ON HUMAN TOLERANCE TO LONG-TERM ACCELERATION

by

P.M. Suvorov

FOREIGN TECHNOLOGY DIVISION

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Г г	*Г г*	G, g	У у	*У у*	U, u
Д д	*Д д*	D, d	Ф ф	*Ф ф*	F, f
Е е	*Е е*	Ye, ye; E, e*	Х х	*Х х*	Kh, kh
Ж ж	*Ж ж*	Zh, zh	Ц ц	*Ц ц*	Ts, ts
З з	*З з*	Z, z	Ч ч	*Ч ч*	Ch, ch
И и	*И и*	I, i	Ш ш	*Ш ш*	Sh, sh
Й й	*Й й*	Y, y	Щ щ	*Щ щ*	Shch, shch
К к	*К к*	K, k	Ъ ъ	*Ъ ъ*	"
Л л	*Л л*	L, l	Ы ы	*Ы ы*	Y, y
М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

*ye initially, after vowels, and after ъ, ь; e elsewhere.
When written as ё in Russian, transliterate as yё or ё.

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English	Russian	English	Russian	English
sin	sin	sh	sinh	arc sh	$\sinh^{-1}$
cos	cos	ch	cosh	arc ch	$\cosh^{-1}$
tg	tan	th	tanh	arc th	$\tanh^{-1}$
ctg	cot	cth	coth	arc cth	$\coth^{-1}$
sec	sec	sch	sech	arc sch	sech^{-1}
cosec	csc	csch	csch	arc csch	csch^{-1}

Russian	English
rot	curl
lg	log

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EFFECT OF AGE, OCCUPATION, AND PHYSICAL TRAINING ON HUMAN TOLERANCE TO LONG-TERM ACCELERATION

P.M. Suvorov.

The effect of the age, occupation and physical training on the human tolerance to long-term accelerations ($+G_z$ and $-G_x$) was investigated 427 test subjects — fighter-pilots, engineers, physicians and research workers were used in the experiments. The lowest tolerance was found in the test subjects of the age range of 20—24 while the highest in those of 30—34. The test subject of 40—49 showed a decreased tolerance to accelerations. Certain differences in the acceleration tolerance and pattern of physiological reactions were found between pilots and representatives of other professions. As to the sportsmen, gymnasts, weight-lifters and acrobats they exhibited a better tolerance as compared to long-distance runners, football players and skiers who showed the tolerance level similar to that of people who did not go in for sports regularly.

The problem of determining the most promising age range for pilot and astronaut activity is a topic that has been addressed many times (Schubert, Ya. F. Samter, Booth, A.N. Babiychuk, P.I. Yegorov et al.). According to Voas and co-authors and the Army-Navy Air-Force Journal and Register (1962, 28/4, vol. 99, N 35, p. 4), the age limit of 36-39 years has been established for American astronauts.

Yet specialized experimental materials which might justify this position (particularly acceleration tolerance) are scarce.

In addition, data concerning the significance of occupation and physical training in human acceleration tolerance are contradictory. Bergin mentions the fact that some pilots have a lower tolerance to accelerations than do some nonpilots. On the other hand, Schubert, D.Ye. Rozenblyum, ... Flekkel', A.I. Odinov, A.A. Sergeyev (1957, 1967), P.M. Suvorov et al beli[illegible] that systematic flight activity (work) increases the body's tolerance to the effect of accelerations. Lovelace (1961, 1964), Booth, and Colcum are of the opinion that only fighter pilots should qualify as astronaut candidates.

With respect to physical training, both Bergin and Armstrong think that athletes have a lower tolerance to accelerations than do nonathletes. Kenneth and co-authors have not found higher tolerance to accelerations (G_z) among persons trained as runners. A.P. Popov, Ye.A. Derevyanko, F.M. Gorskiy, V.I. Stepantsov and G.F. Khlebnikov, P.V. Vasil'yev and A.R. Kotovskaya, Ye.A. Poruchikov et al. believe on the contrary that specific physical training increases the body's tolerance to accelerations. The importance of this set of problems in flight medicine and astronaut screening prompted the undertaking of experimental research.

METHODS

The resistance of subjects to the effect of accelerations (G_z) was determined on a centrifuge with a radius of 3.6 m by a series of spins at accelerations of 3-7 g (30 sec each) and increasing at a rate of 0.4-0.5 g/sec which were conducted at intervals of 5 min. In some cases the same tests were repeated (within 1-2 days) to further refine tolerance thresholds.

Maximally tolerable accelerations are defined here as accelerations beyond which one unit (1g) would result in decompensation phenomena (in the form of visual disturbances, group or polytopic extrasystole or pronounced aftereffects in the form of marked pallor of the face, hyperhydrosis, nausea, vomiting, etc.) regardless of the time of their occurrence - either at the platform or later.

With the back of the chair inclined at an angle of 65° toward the acceleration vector ($+G_x$), transverse accelerations of 6 and 8 g were imposed for 30 sec, increasing at a rate of 0.2 g/sec. Acceleration tolerance was considered good in the absence of signs of decompensation (visual disturbances, group or polytopic extrasystole or marked autonomic symptoms or aftereffects). If one of these criteria was present, then tolerance was considered to be satisfactory. The presence of 2 or 3 symptoms meant that tolerance was low.

The nature of physiological reactions was also compared in the studied groups. For this purpose heart rate, arterial pressure in the vessels of the concha auriculae and the arm, EKG, EEG, respiration rate, and reaction time to light signals were recorded and visual acuity determined.

A group of 427 subjects was studied for the effect of accelerations ($+G_z$). Of this number 300 were healthy (fighter pilots and members of other occupations, including engineers, medical and scientific workers) and 127 were pilots with signs of autonomic vascular instability (AVI). The effect of accelerations ($+G_x$) was studied among a group of 104 healthy subjects (37 pilots and 67 nonpilots). Altogether more than 650 tests were conducted and the data obtained from them statistically processed.

RESULTS OF STUDIES

Table 1 presents averaged data for acceleration tolerance ($+G_z$) in different age groups of healthy subjects and pilots with AVI symptoms.

From the table we learn that the lowest tolerance among healthy persons is observed in the age range of 20-24 years. By 30-39 years tolerance is maximal, but declines again at ages 40-49. Pilots with AVI have the same age dynamic,

but at a lower tolerance level overall (by 1.0 g on the average) than do healthy subjects. In younger age groups and in certain individuals there is a tendency to lose consciousness at accelerations of 5 g. In older groups this phenomenon is not observed, and tolerance to accelerations is stable.

With (advancing) age the pulse rate before rotation and during accelerations of 3 g averaged 9-11 fewer beats (the 4th and 5th group as compared to the 1st and 2nd). However, increasing accelerations up to 5-7 g levelled this difference. In the 5th age group the well-known tendency toward a lower respiration rate was noted in the original state and at accelerations of 3-5 g. Visual acuity in the 1st and 5th groups during acceleration was lower than in the 2-4th groups. Significant individual variations in arterial pressure made it impossible to detect significant age differences. The same can be said for response time to light signals.

The lower acceleration tolerance at ages 20-24 years (as compared to the 2-4 age groups) might be explained by the known lability of neurohumoral mechanisms.

Conversely, the drop in tolerance to accelerations encountered in the age range of 40-49 years depends on the known aging of the organism and associated deviations peculiar to this age (senile hyperopia, latent atherosclerotic processes, etc).

In Table 2, which presents data on tolerance to accelerations ($+G_z$) of fighter pilots and members of other professions, we see that this index averages 0.5 g higher in pilots than in nonpilot personnel. These data are close to those of studies conducted by A.B. Flekkel and A.I. Odinov, in which a difference of 0.7 g was found. Statistically reliable differences were detected in the following parameters: The pulse rate in untrained persons at accelerations of 3-5 g and in the first minute thereafter was higher by 6-19 beats per minute than that of pilots. The respiration rate in untrained subjects at accelerations of 5 g averaged 4 cycles per minute higher than that of trained subjects. Systolic pressure in the vessels of the concha auriculae at small accelerations was greater than in pilots, although at the highest tolerable accelerations it was lower. There was a sharper decline in visual acuity in untrained persons during acceleration and a greater time of reaction to light signals. Analysis of other parameters (EKG, EEG, systolic pressure in the vessels of the arm) did not reveal any substantial differences in the studied groups.

As for the transverse accelerations, which were experienced by the pilots and members of other occupations for the first time, no difference was revealed

in either tolerance to the accelerations or in the nature of the physiological response of the studied groups to them. The only exception to this was response time to light signals. In pilots it was shorter (by 50 msec on the average in the initial state, 40 msec shorter at 6g, 140 msec shorter at 8g) than in subjects from other occupations. The nature of occupational activity **did** seem to make a difference here.

To determine the most promising types of physical training for increasing the body's resistance to accelerations, tolerance to accelerations of 3 and 5 g ($+G_z$) and to 6 and 8 g ($+G_x$) was studied in 101 subjects. The latter were divided into 3 groups with respect to their level of physical training. The 1st group included 22 athletes at levels I and II, who were engaged in sports with predominantly short-term static and dynamic loads (gymnasts, weight-lifters, acrobats). The 2nd group consisted of 29 athletes of levels I and II who participated in sports with predominantly long-term dynamic loads (distance runners, soccer players, skiers). The 3rd group consisted of subjects whose participation in sports was not systematic (50 persons).

The highest percentage (81%) of good tolerance ($+G_z$) was found in persons of the 1st group. The 2nd group had good tolerance in 76% of its members, the 3rd - in 72.4%. Arterial pressure in the vessels of the head during the accelerations was regularly higher in athletes than in nonathletes.

It is important to point out that athletes did not lose consciousness at accelerations of 5 g in a single instance. This is in contrast to the 8.6% of those whose participation in sports was not systematic.

Under transverse accelerations (6 and 8 g) differences in physiological reactions were less noticeable, although the percentage of good tolerance (81.8) even in this case was somewhat higher in the 1st group of athletes. In the 2nd and 3rd groups acceleration tolerance was approximately the same (73% and 75%, respectively). The most informative of the physiological parameters turned out to be the EKG. Persons whose participation in sports was not systematic had a normal EKG under accelerations ($+G_x$) in 38.4% of cases; for athletes of the 2nd group this figure was 57.7%, for athletes of the first - 47.8%. The most typical deviations in EKG reactions under transverse accelerations were extrasystole, migration of cardiac rhythm from the sinus to the atrioventricular node, sinoatrial blockade, inversion of the T_2 wave.

Our data on the better acceleration tolerance of persons engaged in sports with predominantly short-term static and dynamic loads are in agreement with the results of research conducted by Ya.A. Egolinskiy and M.M. Bogorod, P.V. Vasil'yevich and N.N. Uglova, V.I. Stepanov and A.V. Yeremin et al. It appears

that long-term dynamic loads, despite their recognized training of the body to [resist] hypoxia factors (A.A. Sergeyev, 1962 et al.), cause changes in the organism (predominantly the development of muscles in the lower extremities, additional collateral circulation of the blood (V.I Stepantsov), redistribution of circulating blood during the loading period), which to a significant degree eliminate the benefit gained from hypoxia training.

Conversely, gymnastics, strenuous athletics, and acrobatics, which create conditions for proportional development of the muscular system (particularly muscles of the shoulder girdle and abdominal region, whose significance in compensatory responses under accelerations has been shown by Schubert, Lambert, Ye. A. Derevyanko, V.I. Babushkin and co-authors, A.S. Barer et al.), are a more effective means of increasing the body's resistance to accelerations. It is also possible that the mechanisms of compensation involved in the body's response to short-term physical loads of a static-dynamic nature have something in common with those involved in accelerations.

We do not mean to imply that the data presented in this article represent a complete and exhaustive solution to all of the problems posed above. They may, however, prove useful in the screening and training of astronauts and in the medical certification of fighter pilots.

Table 1. Tolerance of accelerations ($+G_z$) by different age groups.

Группа	Возраст обследуемых (в годах)	Переносимость ускорений (G_z)			
		для здоровых лиц		для лиц с СВН	
		число обследуемых	средняя устойчивость (в g)	число обследуемых	средняя устойчивость (в g)
1-я	20—24	38	5.60±0.03*	21	4.40±0.28
2-я	25—29	89	6.00±0.10	39	4.71±0.20
3-я	30—34	41	6.10±0.10	37	5.10±0.19
4-я	35—39	23	6.00±0.12	20	5.20±0.20
5-я	40—49	10	5.70±0.15	10	4.70±0.40
Всего по группам		201	5.9±0.04	127	4.87±0.09

Key: 1 - group; 2 - age of subjects (in years); 3 - tolerance of accelerations ($+G_z$); 4 - for healthy subjects; 5 - for subjects with AVI; 6 - number of subjects; 7 - average tolerance (in g); 8 - total, by groups. * m - mean error.

Table 2. Tolerance of accelerations by healthy fighter pilots and by members of other occupations.

Группа	Группа обследуемых	Число обследуемых	Средний возраст по группе (в годах)	Средняя устойчивость к ускорениям ($+G_z$, в g)	Достоверность различия
1-я	Здоровые летчики истребительной авиации	200	28,5	5,80±0,05*	
2-я	Здоровые лица других профессий (инженеры, врачи и т. д.)	100	26,8	5,30±0,09	$t = 5{,}00$ $P < 0{,}001$

Key: 1 - group; 2 - group of subjects; 3 - number of subjects; 4 -average age of group (in years); 5 - average tolerance to accelerations ($+G_z$, in g); 6 - reliability of difference; 7 - healthy fighter pilots; 8 - healthy persons of other occupations (engineers, physicians, etc.). * m - mean error.

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